

### **Elastic properties of $\text{NdFe}_4\text{P}_{12}$**

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$\text{ReFe}_4\text{P}_{12}$ , crystallized in the filled skutterudite structure, exhibits various interesting physical properties at low temperature depending on  $\text{Re}$ ; i.e., superconducting  $\text{LaFe}_4\text{P}_{12}$  below 4.1 K, semiconducting  $\text{CeFe}_4\text{P}_{12}$  and ferromagnetic  $\text{NdFe}_4\text{P}_{12}$  below 1.9 K.<sup>1)</sup> Furthermore, recent studies revealed the existence of heavy mass electrons in  $\text{PrFe}_4\text{P}_{12}$ .<sup>2)</sup> We have investigated the elastic properties of  $\text{NdFe}_4\text{P}_{12}$  by means of the ultrasonic measurement for the first time to elucidate the crystalline electric field (CEF) ground state of  $\text{Nd}^{3+}$ . The elastic constants  $C_{11}$ ,  $(C_{11}-C_{12})/2$  and  $C_{44}$  increase monotonically with decreasing temperature. However, a pronounced softening has been observed in all elastic constants around  $T_c = 1.9$  K, which may be due to the CEF ground state degenerated by the quadrupolar moment. Furthermore, we have found the upturn in  $(C_{11}-C_{12})/2$  around 20 K. Our results indicate that the  $\Gamma_8^{(1)}$  quartet state is plausible as the CEF ground state.

1) M. S. Torikachvili *et al.*: Phys. Rev. B36 (1987) 8660.

2) H. Sugawara: private communication.